

PATENT SPECIFICATION

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(54) A PLANT FOR STORING AND PUMPING AIR FOR POWER STATION INSTALLATIONS

(71) We, RHEINISCH-WESTFÄLISCHES ELEKTRIZITÄTSWERK AG., a company organized under the laws of the Federal Republic of Germany, of 43 Essen, Kruppstrasse 5, Germany, do hereby declare the invention for which we pray that a patent may be granted to us and the method by which it is to be performed, to be particularly described in and by the following statement:—

This invention relates to a plant for storing and pumping air for power station installations having at least one gas turbine set consisting of an air compressor, a combustion chamber, a gas turbine and an electric generator, the plant consisting of an underground air reservoir in a cavity in the ground and a constant-pressure water basin, the underground air reservoir and the water basin being hydraulically connected by a vertical shaft, and the underground air reservoir being able to be charged up during off-peak hours from the compressor through suitable connecting pipes, and during peak hours to be connected to the combustion chamber of the gas turbine set instead of the compressor. — "Constant-pressure water basin" means that the water basin and the underground air reservoir are actively associated for what is known as "constant pressure storage and delivery". When empty of air the underground air reservoir is filled with constant-pressure water. During the filling operation the compressed air pushes out the water, which then goes via the vertical shaft into the water basin which is on the surface. At any time the only ruling factor for the pressure of the stored air is the difference between the upper and lower water levels. Consequently, with a sufficient depth of the underground air reservoir the pressure of the stored air can be considered as being constant. An underground air reservoir with an associated

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constant-pressure water basin has quite considerable advantages compared to an underground air reservoir in which the pressure declines as the stored air is drawn off. In the first place it can be of significantly smaller design, as the air can be drawn off almost completely with the full storage pressure, and secondly it makes available for the combustion chamber of the gas turbine a supply of air which is always at the same pressure.

In the case of plants for storing and pumping air of the kind described which are known (in theory), the underground air reservoir is a concrete construction with at least a double concrete shell and a seal in between to make it airtight and watertight. The prevailing principle of construction is that an underground air reservoir must be of watertight and airtight construction, irrespective of whether or not it is actively associated with a constant-pressure water basin. This is extremely expensive, especially as a high pressure of the compressed air demands a great depth for the underground air reservoir and the necessary constructional work to be carried out at that depth.

The object of the present invention is to provide a plant for storing and pumping air of improved or simplified construction.

According to the present invention a plant for storing and pumping air for power station installations having at least one gas turbine set consisting of an air compressor, a combustion chamber, a gas turbine, and an electric generator, the plant comprising an underground air reservoir in a cavity in the ground having a sealing dome consisting of a sealing film which lies against the wall of the cavity and is open at its bottom edge to the floor of the cavity, and a constant-pressure water basin as hereinbefore defined, the underground air reservoir and the constant-pressure water

basin being hydraulically connected by a vertical shaft, and the underground air reservoir being able to be charged up during off-peak hours from the compressor, driven, during off-peak hours, either by the gas turbine and/or electric generator or by an electric motor, through suitable connecting pipes, to a filled condition in which the constant-pressure water still covers a bottom edge of the sealing dome while in an emptied condition some air still remains in the sealing dome in the region of the top of the cavity, the underground air reservoir during peak hours, being connected to the combustion chamber of the gas turbine instead of the compressor.

The gas turbine preferably comprises a high pressure, hot air turbine and a low pressure, combustion gas turbine.

"Filled condition" denotes the operational state with the maximum air content. "Emptied condition", on the other hand, denotes the operational state with the minimum air content. In a plant according to the invention it is not essential, from the point of view of its functioning, that the sealing dome and therefore the sealing film be mechanically bonded to the ground. However, for reasons of easier installation, it can be an advantage to make the arrangement such that the sealing dome is bonded at some points to the wall of the cavity. The sealing dome itself can with advantage consist of a film of synthetic material, but rubber or other suitable materials can be used. The invention also includes bringing the intermediate space between the sealing dome and the wall of the cavity into pressure-equalising communication with the constant-pressure water, by means of an equalising device.

The invention breaks away from the view that in an air storage and pumping plant of the category described in the invention the underground air reservoir must be made watertight and airtight. The invention starts from recognising that airtightness is sufficient. Consequently, the expensive concrete construction in the form of at least a double concrete shell with a seal in between, which has hitherto been considered necessary, can be dispensed with. This reduces the cost of the whole air storage and pumping plant to a very considerable degree, and at the same time enables modern methods of construction with earth-boring machines to be easily used.

The invention will now be further described, by way of example, with reference to the accompanying drawings, in which:—

Figure 1 shows an air storage and pumping plant for power station installations in accordance with the invention;

Figure 2 is portion A of Figure 1, enlarged;

Figure 3 corresponds to Figure 2, but shows an alternative construction;

Figure 4 is portion B of Figure 3, enlarged; and

Figure 5, on the same scale as Figure 4, is a horizontal section through a portion corresponding to Figure 4, with an alternative type of equalising device.

The air storage and pumping plant shown in the drawings is intended for power station installations which have at least one gas turbine set consisting of an air compressor 4, a combustion chamber 2, a gas turbine 1 and an electric generator 3. The plant comprises an underground air reservoir in a cavity 5 in the ground, and an associated constant-pressure water basin 6. The underground air reservoir in the cavity 5 and the water basin 6 are hydraulically connected by a vertical shaft 7. The underground air reservoir can be charged up during off-peak hours from the compressor 4, then driven either by the gas turbine and/or electric generator, or by an electric motor, through suitable connecting pipes 8, whilst in peak hours it is connected to the combustion chamber of the gas turbine set instead of the compressor 4. It will be seen from Figure 2 in particular that the underground air reservoir has a sealing dome 10 which merely lies against the wall of the cavity 5, and is open at its bottom edge 9 to the floor of the cavity, in the manner of a diving bell. This sealing dome consists of a suitable sealing film e.g. of synthetic material. Moreover, the underground air reservoir is so set up that in the filled condition, i.e. the maximum air content, the constant-pressure water still covers lower edge 9 of the sealing dome 10, whilst in the emptied condition, i.e. the minimum air content, some air still remains in the region of the top of the cavity 5. Also indicated in Figure 2 is that the sealing dome 10 can be bonded at some points 11 to the wall of the cavity 5 for the purpose of installation, but this is not essential from the functional standpoint.

In the air storage and pumping plant illustrated, the underground air reservoir readily complies with the requirement of airtightness, (watertightness not being demanded nor necessary) by the sealing dome 10 covering the wall of the cavity 5 in the diving bell manner. There is no need whatever for it to be bonded to the wall of the cavity 5 over all its surface. The underground air reservoir must be filled with compressed air only until the low water level in the reservoir is still above the bottom edge 9 of the sealing dome 10. When water in the ground is at a higher pressure

than the compressed air, and consequently escapes through fissures 12 in the cavity 5, this water can flow away behind the sealing dome 10 or the sealing film. The functioning of the underground air reservoir is in no way adversely affected by this. If, on the other hand, there are open fissures in the ground which do not contain water, these will fill up with water. Before starting up an underground air reservoir, which can be considered as consisting of element 10, first of all the reservoir should be filled with water for some time so that the ground can fill up again with water after the excavation work has been completed. When the air reservoir is full of air, that is to say when the water level is lowest, there exists in the top of the air reservoir a pressure difference corresponding to the difference in height between the water level and the reservoir top. The sealing film or the sealing dome 10 is pressed by this pressure difference against the wall of the cavity 5. When the air reservoir is empty, that is to say when the water level has risen, there always remains a small amount of air in the reservoir, so that the sealing dome 10 is pressed against the wall of the cavity. Therefore, after having once been started up, the sealing dome 10 remains firmly held in its initially determined position because of the internal pressure.

In order to ensure that a space Z (Figure 3) between the sealing dome 10 and the wall of the cavity 5 is always filled with water, and consequently to ensure that the sealing dome 10 receives, so to speak, hydrostatic support, there is provided, a compensating device, the result of which is that the space Z is always in pressure-equalising communication with the constant-pressure water. In Figures 3 and 4 the compensating device consists of a pipe 13 running from the bottom part to the top part of the cavity. Of course, one could also use half of a pipe lying against the wall of the cavity 5. On the other hand, in alternative construction of Figure 5, the arrangement is such that the compensating device is a channel 14 made in the wall of the cavity 5. There is also indicated in Figure 3 that the bottom edge 9 of the sealing dome 10 can be intumed, so that it does not rest against the cavity 5, and consequently constant-pressure water can enter here.

WHAT WE CLAIM IS:—

1. A plant for storing and pumping air for power station installations having at least one gas turbine set consisting of an air compressor, a combustion chamber, a gas turbine, and an electric generator, the plant comprising and underground air reservoir in a cavity in the ground having a

sealing dome consisting of a sealing film which lies against the wall of the cavity and is open at its bottom edge to the floor of the cavity, and a constant-pressure water basin as hereinbefore defined, the underground air reservoir and the constant-pressure water basin being hydraulically connected by a vertical shaft, and the underground air reservoir being able to be charged up during off-peak hours from the compressor, driven, during off-peak hours, either by the gas turbine and/or electric generator or by an electric motor, through suitable connecting pipes, to a filled condition in which the constant-pressure water still covers a bottom edge of the sealing dome while in an emptied condition some air still remains in the sealing dome in the region of the top of the cavity, the underground air reservoir during peak hours, being connected to the combustion chamber of the gas turbine instead of the compressor.

2. A plant as claimed in Claim 1, wherein the gas turbine comprises a high pressure, hot air turbine and a low pressure, combustion gas turbine.

3. A plant for storing and pumping air as claimed in Claim 1 or Claim 2, wherein the sealing dome is bonded at some points to the wall of the cavity.

4. A plant for storing and pumping air as in any preceding Claim, wherein the sealing dome is made from a film of synthetic material.

5. A plant for storing and pumping air as claimed in any preceding Claim, wherein a space formed between the sealing dome and the cavity is in pressure-equalising communication with the constant-pressure water via an equalising device.

6. A plant for storing and pumping air as claimed in Claim 5, wherein the equalising device consists of at least one pipe or half a pipe which is laid along the wall of the cavity and runs from the bottom part to the top part of the cavity.

7. A plant for storing and pumping air as claimed in Claim 5, wherein the equalising device has at least one channel made in the wall of the cavity.

8. A plant for storing and pumping air as claimed in Claim 5, wherein the bottom edge of the sealing dome is intumed so that constant pressure water can, between the wall of the cavity and the sealing dome, gain access to said space.

9. A plant for storing and pumping air for power station installations substantially as hereinbefore described with reference to Figures 1 and 2 of the accompanying drawings.

10. A plant for storing and pumping air for power station installations substantially as hereinbefore described with reference to

Figures 3 and 4 of the accompanying drawings.

11. A plant for storing and pumping air for power station installations substantially as hereinbefore described with reference to Figure 5 of the accompanying drawings.

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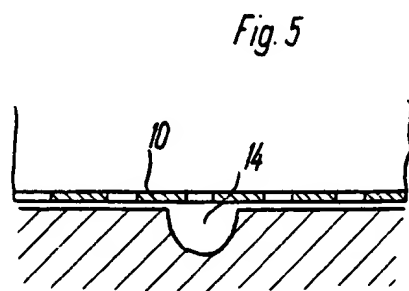
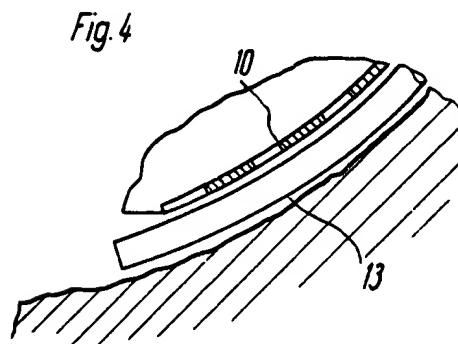
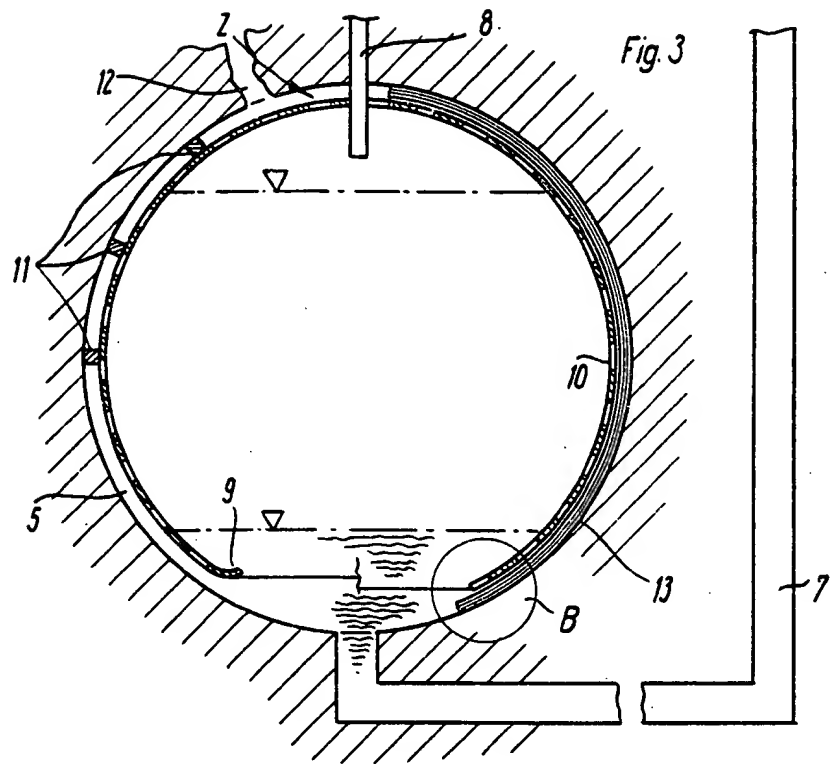
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COMPLETE SPECIFICATION

3 SHEETS

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SHEET 3



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SHEET 2

Fig. 2

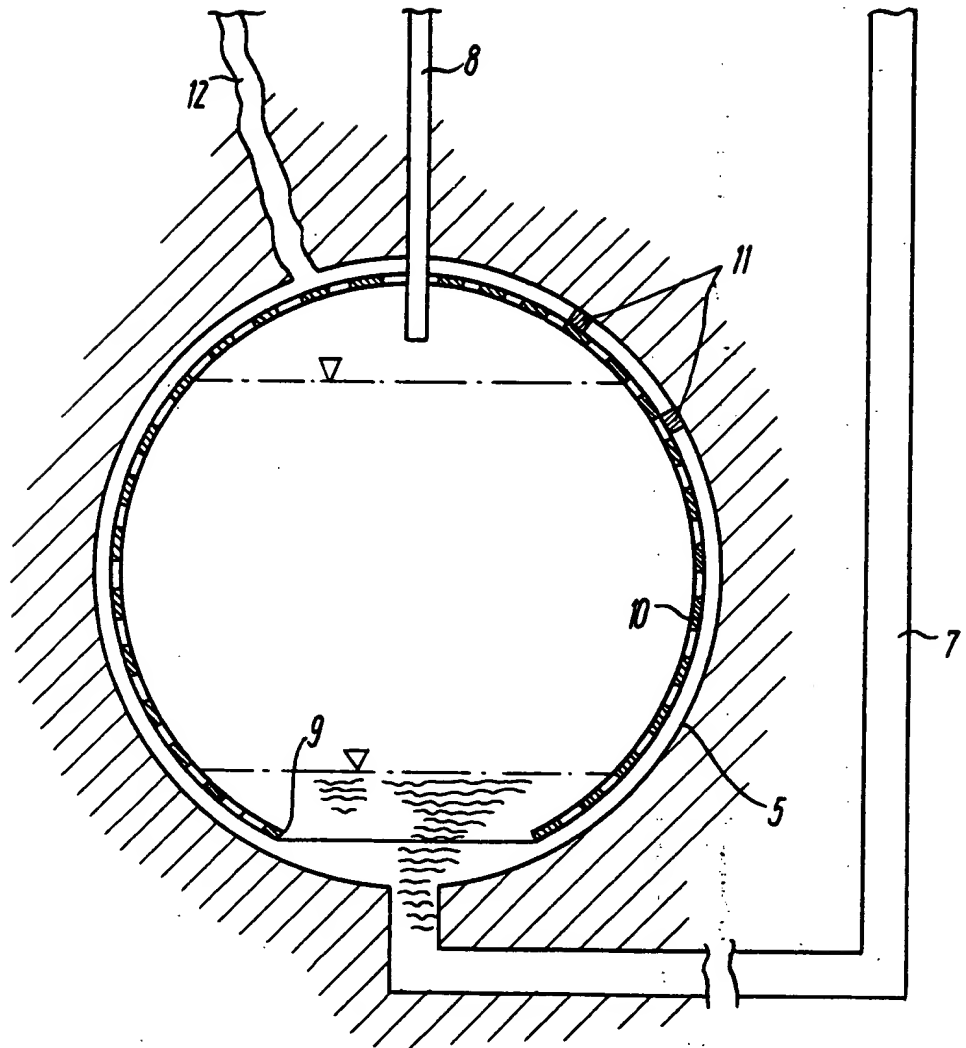


Fig. 1

